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COMPREHENSIVE BASIN STUDY ON SABINE RIVER AND TRIBUTARIES, TEXAS AND LOUISIANA. APPENDIX E. WATER SUPPLY AND WATER QUALITY CONTROL

Federal Water Pollution Control
Administration
Dallas, Texas

September 1967

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CONPREHENSIVE BASIN STUDY

ON

SABINE RIVER AND TRIBUTARIES, TEXAS AND LOUISIANA

APPENDIX E

WATER SUPPLY AND WATER QUALITY CONTROL

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region
Dallas, Texas

UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Temple, Texas

SEPTEMBER 1967

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COMPREHENSIVE BASIN STUDY
ON
SABINE RIVER AND TRIBUTARIES, TEXAS AND LOUISIANA

APPENDIX E

WATER SUPPLY AND WATER QUALITY CONTROL

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COMPREHENSIVE BASIN STUDY
ON
SABINE RIVER AND TRIBUTARIES, TEXAS AND LOUISIANA

APPENDIX E - WATER SUPPLY AND WATER QUALITY CONTROL

INTRODUCTION

1. REQUEST AND AUTHORITY.-

a. Federal Water Pollution Control Administration.- The U. S. Army Engineer District, Fort Worth, Texas in a letter dated July 12, 1962, requested the U. S. Department of Health, Education, and Welfare to investigate and report on the ". . .municipal and industrial water requirements, the quality of water, the extent of existing and potential pollution as well as the need for and the benefits from conservation storage for purposes of municipal and industrial water supply and of water quality control. . . ." in the Sabine River basin, Texas and Louisiana. At a later date the study was expanded and given comprehensive status as set forth by the Senate Select Committee on National Water Resources, in accordance with the Water Resources Planning Act, as amended (42 U.S.C. 1962 et seq.), dated July 22, 1965.

The water supply portion of this study was made in accordance with the Memorandum of Agreement, dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare relative to the Water Supply Act of 1958, as amended (43 U.S.C. 390b). The water quality control aspects are considered under authority of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.). Responsibility for these activities was transferred from the Department of Health, Education, and Welfare to the Department of the Interior by Reorganization Plan No. 2 of 1966, effective May 10, 1966.

b. Soil Conservation Service.- The participation of the U. S. Department of Agriculture in the Comprehensive Study, Sabine River and Tributaries, Texas and Louisiana, is under authority provided by Section 6 of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, as amended). The act is administered by the Soil Conservation Service of the U. S. Department of Agriculture. Section 6 of the Act authorizes the Department to cooperate with other Federal, State, and local groups or agencies in surveys and investigations of river basins as a basis for development of coordinated programs.

2. PURPOSE AND SCOPE.- The purpose and scope of this report are as follows:

a. Determine present water use and estimate future water requirements.

b. Determine capabilities and suitabilities of existing and potential water resources to meet current and future needs.

c. Estimate the effect of present and future return flows on the quality of waters in the basin.

d. Determine the need for and value of storage in Federal reservoir projects for water supply and/or water quality control.

The investigations made were coordinated with all appropriate Federal and State agencies.

3. RELATIONSHIP TO OTHER PORTIONS OF THE REPORT.- This Appendix forms the basis for the water supply and water quality control requirements adopted by the Coordinating Committee for the comprehensive report on the Sabine River basin, Texas and Louisiana. Selected data used herein were extracted from the other Appendixes. The Economic Base Study Appendix data, in conjunction with estimated unit water uses, were used to determine water requirements.

4. BACKGROUND.- The Sabine River drains an area of about 7,400 square miles in eastern Texas, and 2,300 square miles in western Louisiana. The basin is crescent-shaped, having a length of about 300 miles and an average width of about 30 miles. It includes all or parts of 20 counties in Texas, and 8 parishes in Louisiana. The river rises in northern Hunt County, Texas, flows southeastward to the Texas-Louisiana border near Logansport, Louisiana, and then forms the boundary between the two States as it flows southward to its mouth at Sabine Lake, an arm of the Gulf of Mexico. For this investigation, the basin has been divided into four subbasins of suitable size to maintain a reasonable degree of homogeniety of economic, hydrologic, and geographic factors. See Plate 1.

Surface waters of the Sabine River basin are generally of excellent chemical quality. Total dissolved solids concentrations range from 100 to 200 milligrams per liter (mg/l), chloride concentrations are generally less than 20 mg/l, and hardness in much of the basin is less than 60 mg/l.

The basin has an abundant supply of surface water of excellent quality, but uneven distribution of runoff makes reservoirs necessary in order to provide dependable water supplies.

A

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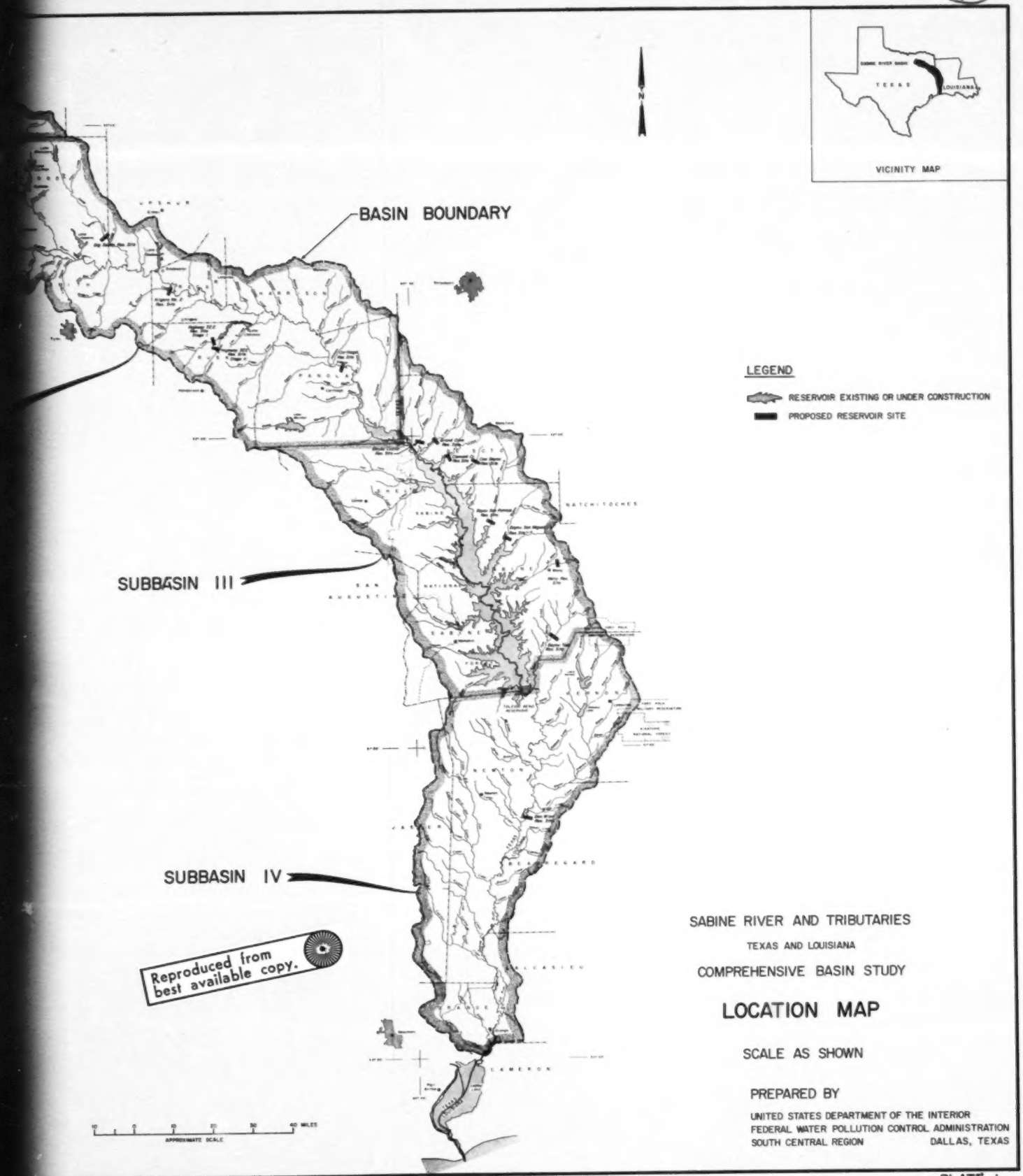

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SABINE RIVER AND TRIBUTARIES

TEXAS AND LOUISIANA

COMPREHENSIVE BASIN STUDY

LOCATION MAP

SCALE AS SHOWN

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UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTH CENTRAL REGION DALLAS, TEXAS

In addition, about 150,000 acre-feet per annum of ground water are estimated to be available from the primary and secondary aquifers of the Sabine River basin. In general, this ground water is of good to excellent quality for all uses except irrigation. The ground water in the upper basin generally is of poor quality for irrigation, due mainly to the high sodium hazard which is expressed as Sodium Adsorption Ratio (SAR). Continued use of these waters in large amounts for irrigation would result in damage to the soil. Ground water near the coast, in Newton and Orange Counties, Texas, normally is of good quality for irrigation.

5. FINDINGS.-

a. In 1960, municipal and industrial water use in the basin was 77 million gallons per day (mgd).

b. Municipal and industrial waste discharged to the Sabine River and tributaries in 1960 amounted to 17 mgd and 39 mgd, respectively. All municipalities of significant size currently provide secondary waste treatment, and most industries treat their wastes to some degree or have facilities in the planning stage.

c. The surface waters of the Sabine River basin are generally of excellent chemical quality. Total dissolved solids concentrations range from 100 to 200 milligrams per liter (mg/l), chloride concentrations are generally less than 20 mg/l, and hardness in much of the basin is less than 60 mg/l. Local changes in the quality occur at Grand Saline in Van Zandt County, Texas due to a natural brine emission, in Lake Fork, Rabbit, and Socagee Creeks due to oilfield pollution, and near some of the larger municipalities due to municipal and industrial wastes.

d. In general, the quality of the ground water in the basin is good to excellent, except for the purpose of irrigation in Subbasin I, with the following range of average concentrations in the primary aquifers: Total dissolved solids, 237 to 878 mg/l; chlorides, 51 to 160 mg/l; sulfates, 5 to 39 mg/l; and hardness, 40 to 46 mg/l. The primary aquifer in Subbasin I has a sodium hazard measured in SAR of 20 to 100, and salinity hazard measured in specific conductance of 300 to over 1,000 micromhos.

6. CONCLUSIONS.-

a. Municipal and industrial water requirements in the Sabine River basin are expected to increase to 236 mgd in 1980, 412 mgd in 2000, 766 mgd in 2020, and 1,519 mgd in 2075.

b. It is anticipated that municipal and industrial waste discharged to the watercourses of the basin will increase to 158 mgd in 1980, 278 mgd in 2000, 509 mgd in 2020, and 1,006 mgd in 2075.

c. With conditions in the Sabine River basin as presently projected and with the selected target concentrations of the indicator pollutants, dilution water for quality control is not anticipated in the foreseeable future.

d. Based on in-basin water requirements, storage in Federal reservoirs is needed as follows: 29 mgd by 1980, 31 mgd by 2000,

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117 mgd by 2020, and 841 mgd by 2075. Out-of-basin water transfer would increase these needs by 200,000 acre-feet per year (178 mgd) by 1980, as requested by the Texas Water Development Board.

e. To meet the projected municipal and industrial water requirements, eight Federal projects are proposed to be constructed. Of the five Corps of Engineers projects, Mineola and Lake Fork Reservoirs are needed by the year 1980, Big Sandy Reservoir by 2000, Carthage Reservoir by 2020, and Bon Weir Reservoir after 2020. The three Soil Conservation Service projects, Canton, Grand Saline, and Many Reservoirs, are needed by the year 1980.

f. Minimum annual values of benefits of storage for water supply in the proposed Corps of Engineers projects, based on the cost of the most likely alternative to the project (single-purpose impoundments at the project site), are as follows:

Reservoir	Annual Water Supply Benefits
Total Requirement (includes out-of-basin transfer)	
Mineola	$1,421,000
Lake Fork	1,734,000
Big Sandy	400,000
In-Basin Requirement	
Lake Fork	1,734,000

WATER REQUIREMENTS

7. TYPES OF WATER USE.- Water uses that effect water supplies and the need to develop water supplies in the Sabine River basin are described below.

a. Municipal.- Municipal water as defined herein includes residential, commercial, public, and those industrial uses which can reasonably be reflected in a per capita use figure. Also included in the per capita quantities are losses in distribution systems and treatment plant attenuation.

b. Industrial.- The definition of industrial water use in this study refers to all water which is used by the manufacturing industries, except that supplied from municipal systems, (Standard Industrial Classification, categories 13, 14, and 20 through 39.).1/

c. Power Generation.- Use of water for thermal power generation is reported as a part of the industrial requirement but has been determined separately. Although withdrawal for this purpose is very large, only the consumptive use is appraised.

d. Rural.- So as not to understate the total basin water requirements, an estimate of rural water use was prepared. Rural water requirements are assumed to consist of domestic water for that portion of the population not served by municipal water systems and water for the maintenance of livestock.

e. Irrigation.- The irrigation diversion requirement of an area is the total amount of water diverted from a source to supply the moisture needed by crops for optimum production, plus all transmission losses. Cropping patterns, irrigation efficiencies, distribution and transmission losses were resolved for conditions of the basin.

f. Navigation.- Navigation water requirements are for a proposed channel to Longview.

g. Fish and Wildlife.- Water requirements to sustain fish and wildlife are included where applicable. These are closely related to water quality in that the requirements reflect dilution quantities needed to maintain a particular quality, such as a salinity balance in Sabine Lake and in the associated coastal marshes.

8. PRESENT STATUS.- An inventory of present in-basin water use (1960) by subbasin and type is shown in table 1.

A closer examination of the municipal and industrial water supplies for basin cities of 5,000 population or greater is shown in

table 2. The quantities and qualities, as well as the sources (ground or surface), of the municipal and industrial water supplies are tabulated.

Table 1

Present Water Use

Subbasin	Type of Use	Users Served (1,000's)	Annual Average Use (mgd)	Peak 30-day Requirements (mgd)	Average (gpcd)
I	Mun.	41.8	4.1	7.4	98
	Ind.	-	0.6	1.1	-
	Rural	-	2.0	2.0	-
	Irrig.	-	0.2	1.2	-
	Nav.	-	0	0	-
	F & W	-	0	0	-
	Total	-	6.9	11.7	
II	Mun.	134.7	12.8	23.0	95
	Ind.	-	22.1	39.8	-
	Rural	-	6.6	6.6	-
	Irrig.	-	0.3	1.5	-
	Nav.	-	0	0	-
	F & W	-	0	0	-
	Total	-	41.8	70.9	-
III	Mun.	23.6	2.6	4.7	110
	Ind.	-	0.9	1.6	-
	Rural	-	2.6	2.6	-
	Irrig.	-	0	0	-
	Nav.	-	0	0	-
	F & W	-	0	0	-
	Total	-	6.1	8.9	-
IV	Mun.	98.8	8.5	15.3	86
	Ind.	-	25.8	46.4	-
	Rural	-	3.4	3.4	-
	Irrig.	-	73.8[a]	56.5	-
	Nav.	-	0	0	-
	F & W	-	0	0	-
	Total	-	111.5	121.6	-
BASIN	Mun.	298.9	28.0	50.4	94
	Ind.	-	49.4	88.9	-
	Rural	-	14.6	14.6	-
	Irrig.	-	74.3[a]	59.2	-
	Nav.	-	0	0	-
	F & W	-	0	0	-
	Total	-	166.3	213.1	-
TEXAS BASIN	Mun.	280.5	26.1	47.0	93
	Ind.	-	48.2	86.8	-
	Rural	-	12.3	12.3	-
	Irrig.	-	12.7[b]	53.3	-
	Nav.	-	0	0	-
	F & W	-	0	0	-
	Total	-	99.3	199.4	-
LOUISIANA BASIN	Mun.	18.4	1.9	3.4	103
	Ind.	-	1.2	2.1	-
	Rural	-	2.3	2.3	-
	Irrig.	-	61.6[c]	5.9	-
	Nav.	-	0	0	-
	F & W	-	0	0	-
	Total	-	67.0	13.7	-

[a] Includes 57.4 mgd out-of-basin use.
[b] Includes 1.1 mgd out-of-basin use.
[c] Includes 56.3 mgd out-of-basin use.

Source: Public Health Service [2], Bureau of Business Research [3], Texas Board of Water Eng. [4], Louisiana Department of Public Works [5], and Bureau of the Census [6]

Table 2

Present Municipal and Industrial Water Supplied
for Basin Cities of 5,000 or Greater Population in 1960

State City	Quantity (mgd) Mun.	Ind.	Quality (mg/l) TDS	Cl	NO_3	Source Mun.	Ind.
TEXAS							
Carthage	0.6	1.1	270	35	1	Ground	Mixed
Gladewater	0.6	0.5	99	31	0	Surface	Surface
Greenville	2.2	0.2	150	14	0	Surface	Surface
Kilgore	1.2	0.5	171	16	0	Ground	Ground
Longview	4.5	12.9	102	27	1	Surface	Mixed
Marshall	2.9	1.5	146	35	0	Surface	Surface
Orange	3.5	19.7	426	123	0	Ground	Mixed
LOUISIANA							
Mansfield	0.7	0.2	480	70	1.8	Ground	Ground

Source: Public Health Service,[2/] and Bryant-Currington, Inc.[7/]

The table above shows that the major cities of the basin generally have a water supply of good quality. In addition, present industrial water quality commitments of the Sabine River Authority of Texas, to satisfy existing contracts, have the following quality limits: chlorides, 100 mg/l; turbidity, 330 mg/l; and sulfates, 250 mg/l.

Studies conducted by the Soil Conservation Service indicate that three smaller cities, i.e., Canton and Grand Saline, Texas, and Many, Louisiana, have an inadequate water supply at the present time. These three cities are all located in watersheds that have been determined to be feasible for project development within the next 10 to 15 years. Each of these potential watershed developments include a multiple-purpose structure to include storage for municipal water supply. Present water use for these cities is given in table 3.

Table 3

Present Water Use by Cities
in Soil Conservation Service Project Watersheds

City	Population	Municipal Water Requirement (1,000 gallons per day)
Canton, Texas	2,000	143
Grand Saline, Texas	2,100	271
Many, Louisiana	3,200	420

9. FUTURE WATER REQUIREMENTS.-

a. Municipal.- Estimates of future municipal requirements were based on projected unit uses and population. The several items considered in making projections of per capita municipal water use for this study are as follows:

(1) Past trends - analysis of records from municipalities.

(2) Characteristics of the subbasin - factors peculiar to an area, such as per capita income, precipitation, and climate.

(3) Analysis of other projections - projections made by other agencies, consulting engineers, and the municipalities themselves.

(4) Judgement - after considering and weighing the above factors, discrepancies which existed were resolved by judgement.

Present and projected values of per capita municipal use are shown in table 4.

Table 4

Municipal Per Capita Water Use
(gpcd)

Subbasin	1960	1980	2000	2020	2075
I	98	125	140	160	160
II	95	124	140	160	160
III	110	135	145	160	160
IV	86	115	135	160	160

Future water requirements for cities in Soil Conservation Service project watersheds are shown in table 5.

Table 5

Projected Municipal Water Requirements

City	1,000 gallons per day		
	1980	2000	2020
Canton, Texas	265	424	710
Grand Saline, Texas	501	804	1,340
Many, Louisiana	790	1,306	2,225

b. Industrial.- Future industrial water needs were calculated using projected unit use and economic and population developments. Base year data on industrial water use were combined with employment data and resulted in a unit water use per employee for each of the industrial categories (Standard Industrial Classification 13, 14, and 20 through 39). Consideration involved in economic projections of the labor force required consolidation of some of the industrial categories into groups.

In order to project unit industrial water use, the following assumptions were made:

(1) In presently undeveloped counties where large future developments are projected, the base year unit employee water uses were adjusted to those of surrounding counties where present conditions approach those forecast for the undeveloped counties.

(2) An average net productivity factor (i.e., the multiplier to obtain unit employee use for future years from base year data) was determined as follows: Unit employee industrial water use projections of Resources for the Future, Inc., and the Business and Defense Services Administration prepared for the Senate Select Committee on National Water Resources[8/] were extrapolated and an average curve constructed. The ratio of future years to the 1960 value on the average curve were used to obtain the productivity factors. See table 6. The unit uses were assumed to remain constant after the year 2020.

c. Power Generation.- Information on future water use was gathered from power companies in the area and combined with data developed by the Federal Power Commission and the Edison Electric Institute. Consideration was given to the general locations of future power generation installations and the projected needs apportioned throughout the basin using hypothetical service areas for the several generating plants. These requirements are given, by subbasin, in table 7.

Table 7

Consumptive Water Use
for Thermal Power Generation
(mgd)

Subbasin	2020	2075
I	6.0	14.5
II	16.3	36.3
III	1.5	2.7
IV	34.8	73.6
TOTAL	58.6	127.1

Table 6

Present and Future Unit Industrial Water Use #
(gal. per employee day)

Item	Subbasin I		Subbasin II		Subbasin III		Subbasin IV	
	Present*	2020	Present*	2020	Present*	2020	Present*	2020
Mining (SIC 13, 14)	25	50	1,650	3,300	4,200	8,400	2,600	5,200
Manufacturing								
Furniture, Lumber & Wood (SIC 24, 25)	50	100	90	180	200	400	870	1,740
Primary Metals (SIC 33)	90	180	240	480	240	480	300	600
Food & Kindred Products (SIC 20)	275	550	250	500	560	1,120	90	180
Chemical & Allied Products (SIC 28)	700	1,400	3,200	6,400	200	400	6,260	12,520
Stone, Clay & Glass Products (SIC 32)	370	740	335	670	45	90	45	90
Petroleum Products (SIC 29)	225	450	3,360	6,720	3,360	6,720	3,390	6,780
Pulp & Paper (SIC 26)	450	900	340	680	500	1,000	2,300	4,600
Other Nondurables (SIC 30, 31)	45	90	280	560	50	100	150	300
Fabricated Metals and Machinery (SIC 34, 35, 36, 37, 38)	80	160	375	750	50	100	70	140
Textiles and Apparel (SIC 22, 23)	40	80	35	70	20	40	65	130
Printing, Publishing and Not Elsewhere Classified (SIC 27, 39)	20	40	20	40	20	40	20	40

*Source: Bureau of Business Research 3/
Texas Employment Commission 9/

Industrial water use is the input water required, or draft on the water resources, and reflects anticipated recirculation and reuse practices.

d. Rural.- The 2020 and 2075 requirements for rural water are based on a per capita use of 180 gallons per day, of which 80 gpcd is for the maintenance of livestock.

e. Irrigation.- Future irrigation water diversions were based on full development of the potentially irrigable lands within the basin and those adjacent areas that can be irrigated with water diverted from the basin. There are 162,200 acres that can be considered as the full irrigation potential. This acreage is comprised of soils that are nearly level and respond favorably to irrigation. Lands far removed from a water source and lands that will be inundated by expected major reservoir development were not included.

f. Navigation.- The Corps of Engineers anticipate that a barge channel to Longview, with eight 84- by 600-foot navigation locks, would be economically justified for construction by the year 2000. Water requirements for navigation on the Sabine River are based on an increasing number of lockages per day to accommodate prospective commerce in the area. For purposes of this appendix, navigation requirements are consumptive values, i.e., water released to the Gulf of Mexico. These requirements are expected to reach 16.5 mgd by 2000, 18.6 mgd by 2020, and 19.1 mgd by 2075. A more detailed report of these requirements is presented in the Navigation Appendix of this report.

g. Fish and Wildlife.- The encroachment of salt water from the Gulf of Mexico into Sabine Lake and Sabine River varies with the inflow of fresh water from the Sabine and Neches Rivers. Fish and wildlife water needs were estimated on the basis of insuring a continuous source of fresh water into Sabine Lake for sport and commerical fishing, and waterfowl.

The Bureau of Sport Fisheries and Wildlife has made a preliminary estimate of the total fresh water discharge from the Sabine and Neches Rivers required to preserve the estuarine fisheries in Sabine Lake, and in the associated Gulf of Mexico. This figure is a minimum of 1.1 million acre-feet annually, of which the Sabine River should contribute at least 600,000 acre-feet annually.

Water requirements for maintenance of optimum conditions for wildlife resources on approximately 110,000 acres of coastal marshes lying in Louisiana adjacent to Sabine Lake are problematical. The Sabine National Wildlife Refuge, an installation of the Bureau of Sport Fisheries and Wildlife, occupies about 50,000 acres of this area. Any significant reduction in fresh water inflows into Sabine Lake may be expected to lower the quality of vegetation and carrying capacity of these marshes. This is expected to occur in the future even without Federal water project development in the Sabine and Neches River basins. Structural salinity control measures in waterways between the marshes

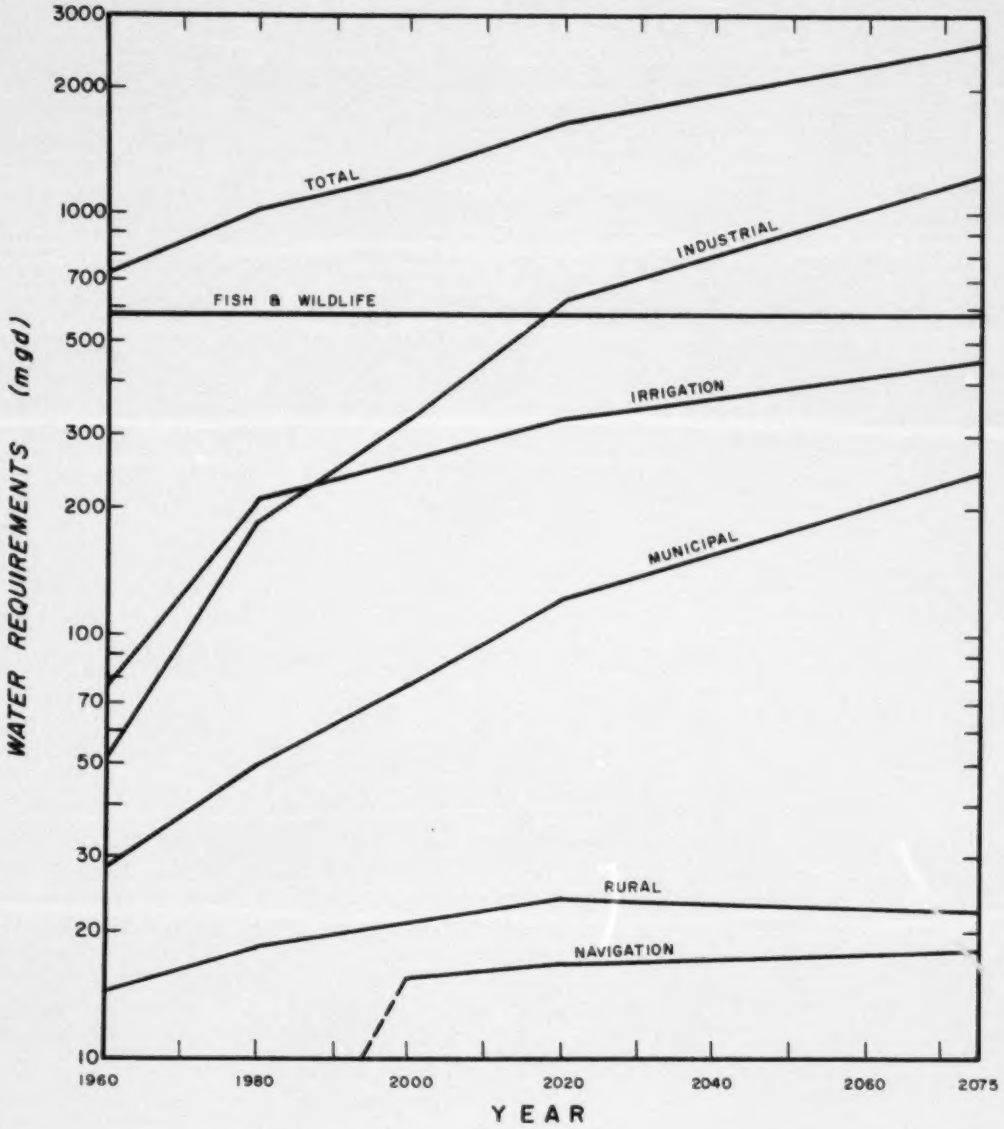
and the lake likely would be required to prevent lowering the quality of the marshes on the refuge and on private lands. Tentatively, a new supply of fresh water to the refuge also may be required during critical dry periods. First estimates indicate that the rate of diversion needed would be about 200 second-feet, principally during the months of March, April, May, and June. The total annual supply probably would amount to about 50,000 acre-feet.

h. Summary.- The estimated future water requirements by subbasin are shown in table 8. Plate 2 shows existing and future total water requirements.

Table 8

Future Water Requirements

Subbasin	Type of Use	Users Served (1,000's) 1980	2000	2020	2075	Annual Average Requirement (mgd) 1980	2000	2020	2075	Peak 30-Day Water Requirement (mgd) 1980	2000	2020	2075
I	Municipal	61.0	87.5	126.9	281.3	7.6	12.2	20.3	45.0	13.7	22.0	36.5	81.0
	Industrial	-	-	-	-	2.5	4.2	9.0	21.4	4.5	7.6	16.2	38.5
	Rural	-	-	-	-	2.5	2.7	3.0	2.8	2.5	2.7	3.0	2.8
	Irrigation	-	-	-	-	1.6	5.7	9.8	21.2	8.1	31.4	54.8	119.3
	Navigation	-	-	-	-	0	0	0	0	0	0	0	0
	Fish and Wildlife	-	-	-	-	0	0	0	0	0	0	0	0
	Total	-	-	-	-	14.2	26.8	42.1	90.4	28.8	63.7	110.5	241.6
II	Municipal	176.5	232.0	306.3	653.0	21.9	32.5	59.0	104.5	39.4	58.5	88.2	188.1
	Industrial	-	-	-	-	58.1	70.7	91.5	168.4	104.6	127.3	164.7	303.1
	Rural	-	-	-	-	8.5	9.3	10.4	10.1	8.5	9.3	10.4	10.1
	Irrigation	-	-	-	-	3.0	27.6	52.2	121.5	16.5	153.6	290.7	669.4
	Navigation	-	-	-	-	0	0	0	0	0	0	0	0
	Fish and Wildlife	-	-	-	-	0	0	0	0	0	0	0	0
	Total	-	-	-	-	91.5	140.1	203.1	404.5	169.0	348.7	554.0	1,170.7
III	Municipal	36.3	56.0	186.2	203.8	4.0	8.1	13.8	32.6	8.8	14.6	24.8	58.7
	Industrial	-	-	-	-	3.2	6.3	16.3	35.9	5.8	11.3	25.2	64.6
	Rural	-	-	-	-	3.6	4.2	5.0	4.9	3.6	4.2	5.0	4.9
	Irrigation	-	-	-	-	0.2	0.6	1.1	2.3	0.9	3.2	5.5	11.8
	Navigation	-	-	-	-	0	0	0	0	0	0	0	0
	Fish and Wildlife	-	-	-	-	0	0	0	0	0	0	0	0
	Total	-	-	-	-	11.9	19.2	36.2	75.7	19.1	33.3	61.0	140.0
IV	Municipal	134.5	183.0	250.6	459.4	15.4	24.6	40.1	73.5	27.7	44.3	72.2	132.3
	Industrial	-	-	-	-	122.5	253.5	528.1	1,037.6	220.5	456.3	950.6	1,867.0
	Rural	-	-	-	-	4.3	4.9	5.7	5.6	4.3	4.9	5.7	5.6
	Irrigation	-	-	-	-	242.6	240.6	268.5	307.5	673.9	773.4	863.1	988.6
	Navigation	-	-	-	-	0	16.5	18.6	19.1	0	16.5	18.6	19.1
	Fish and Wildlife	-	-	-	-	580.3	580.3	580.3	580.3	580.3	580.3	580.3	580.3
	Total	-	-	-	-	935.1	1,120.4	1,441.3	2,023.6	1,506.7	1,875.7	2,485.5	3,592.9
BASIN	Municipal	408.3	558.5	770.0	1,597.5	49.8	77.4	123.2	255.6	89.6	139.4	221.7	460.1
	Industrial	-	-	-	-	186.3	334.7	642.9	1,262.9	335.4	602.5	1,157.2	2,273.2
	Rural	-	-	-	-	18.9	21.1	24.1	23.5	18.9	21.1	24.1	23.4
	Irrigation	-	-	-	-	247.4	274.5	331.6	452.5	699.4	961.6	1,214.1	1,789.1
	Navigation	-	-	-	-	0	16.5	18.6	19.1	0	16.5	18.6	19.1
	Fish and Wildlife	-	-	-	-	580.3	580.3	580.3	580.3	580.3	580.3	580.3	580.3
	Total	-	-	-	-	1,052.7	1,304.5	1,720.7	2,593.8	1,723.6	2,321.4	3,216.0	5,145.2
TEXAS BASIN	Municipal	380.0	511.5	690.6	1,410.7	46.0	70.5	110.5	225.7	82.8	126.9	198.9	406.3
	Industrial	-	-	-	-	183.7	328.7	627.0	1,223.5	330.7	591.7	1,128.6	2,202.3
	Rural	-	-	-	-	15.8	17.3	19.3	18.8	15.8	17.3	19.3	18.8
	Irrigation	-	-	-	-	39.9	72.1	101.2	183.1	138.3	310.7	473.4	923.0
	Navigation	-	-	-	-	0	8.2	9.3	9.5	0	8.2	9.3	9.5
	Fish and Wildlife	-	-	-	-	267.8	267.8	267.8	267.8	267.8	267.8	267.8	267.8
	Total	-	-	-	-	553.2	764.6	1,135.1	1,928.4	835.4	1,322.6	2,097.3	3,827.7
LOUISIANA BASIN	Municipal	28.3	47.0	79.4	186.8	3.8	6.9	12.7	29.9	6.8	12.5	22.8	53.8
	Industrial	-	-	-	-	2.6	6.0	15.9	39.4	4.7	10.8	28.6	70.9
	Rural	-	-	-	-	3.1	3.8	4.8	4.6	3.1	3.8	4.8	4.6
	Irrigation	-	-	-	-	177.5	202.4	230.4	269.4	361.1	650.9	740.7	866.2
	Navigation	-	-	-	-	0	8.2	9.3	9.5	0	8.2	9.3	9.5
	Fish and Wildlife	-	-	-	-	312.4	312.4	312.4	312.4	312.4	312.4	312.4	312.4
	Total	-	-	-	-	499.4	539.7	585.5	665.2	888.1	998.6	1,118.6	1,317.4



SABINE RIVER AND TRIBUTARIES
TEXAS AND LOUISIANA
COMPREHENSIVE BASIN STUDY

BASIN WATER REQUIREMENTS

PREPARED BY

UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTH CENTRAL REGION DALLAS, TEXAS

PLATE 2

WATER QUALITY CONTROL

10. PRESENT WATER QUALITY.-

a. General.- The surface waters of the Sabine River basin are generally of good quality and within the recommended limits of the U.S. Public Health Service Drinking Water Standards. Variations in concentration of dissolved constituents are primarily influenced by the geology of the area, rainfall, and streamflow characteristics. Present development in the basin, except in isolated small sections, has had a relatively minor influence in the resultant surface water quality.

A summary of present surface water quality indicating maximums, minimums, means, and standard deviations of the concentrations of various water quality indicators at representative stations is shown in table 9. It should be noted that sampling procedure restricts the meaningfulness of the dissolved oxygen concentrations.

The quality of ground water differs throughout each aquifer as well as in different aquifers. Four major aquifers, the Carrizo-Wilcox sands, the Catahoula-Oakville-Lagarto sands, the Goliad-Willis-Lissie sands, and the Beaumont sands occur in the Sabine River basin. These are consolidated into two primary aquifers hereinafter referred to as the Carrizo-Wilcox aquifer in the upper basin, and the Gulf Coast aquifer in the lower basin. In addition, the Woodbine sands, the Mount Selman sands, and the Sparta sands, classified as minor aquifers, occur in the watershed. In general, the quality of the ground waters available in the Sabine River basin is good to excellent. Chemical analyses of water from selected wells in the primary aquifers of the basin are shown in table 10.

b. Pollution Loads.-

(1) Municipal.- All municipalities of significant size in the Sabine River basin provide secondary waste treatment. Most smaller cities are either providing secondary treatment at present or have plants under construction or in the planning stage. Present municipal waste discharges are shown in table 11.

(2) Industrial.- In 1960 there were 22 industrial waste discharges to the Sabine River and tributaries. These industries had a combined return flow of 38.7 mgd, [10 11/] and contribute the following pollutant loads to the stream:

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Table 9

Present Surface Water Quality

Stream and Location River Mile	Indicator	Number of Samples	Data Distribution	Concentration (mg/l)* Mean	Standard Deviation	Max.	Min.
Sabine River RM 501	DO	161	Arith.	5.8	2.3	10.2	0.6
	pH	161	Arith.	7.0	0.4	8.0	3.4
	Cl^-	161	Log.	69	4.1	3,600	3
Sabine River RM 461	DO	152	Arith.	5.9	2.1	10.2	0.5
	pH	153	Arith.	7.2	0.3	8.1	6.3
	Cl	153	Log.	72	2.9	1,960	8
Lake Fork Creek RM 445, 23	DO	155	Arith.	5.7	2.3	10.5	0.2
	pH	155	Arith.	6.8	0.4	7.9	2.5
	Cl	155	Log.	117	2.2	4,700	3
Sabine River RM 418	DO	163	Arith.	5.5	2.1	10.9	1.0
	pH	162	Arith.	7.1	0.4	8.3	6.3
	Cl	163	Log.	65	1.9	900	8
Big Sandy Creek RM 412, 7	DO	152	Arith.	6.0	2.0	11.1	1.1
	pH	151	Arith.	6.8	0.4	8.2	5.9
	Cl	152	Log.	40	1.6	147	8
Sabine River RM 397	DO	153	Arith.	6.9	1.6	10.3	1.1
	pH	154	Arith.	7.1	0.4	8.1	4.9
	Cl	154	Log.	59	1.8	530	8
Sabine River RM 362	DO	153	Arith.	6.6	2.0	10.5	0.4
	pH	155	Arith.	7.2	0.5	8.3	5.8
	Cl	155	Log.	92	1.9	273	8
Sabine River RM 339	DO	118	Arith.	5.3	2.4	9.9	0.6
	pH	118	Arith.	7.0	0.4	8.3	6.2
	Cl	118	Log.	87	1.9	216	13
Sabine River RM 267	DO	127	Arith.	4.5	2.5	9.3	0.1
	pH	127	Arith.	7.1	0.4	8.4	6.2
	Cl	127	Log.	72	1.8	348	20
Sabine River RM 195	DO	130	Arith.	6.0	2.0	9.5	1.1
	pH	130	Arith.	7.2	0.4	8.4	6.2
	Cl	130	Log.	60	2.0	232	12
Sabine River RM 140	DO	146	Arith.	6.0	1.7	10.0	1.0
	pH	146	Arith.	7.0	0.4	8.1	5.5
	Cl	146	Log.	44	1.9	278	9
Sabine River RM 98	DO	68	Arith.	7.7	1.2	11.2	5.4
	pH	151	Arith.	7.1	0.4	8.3	6.1
	Cl	151	Log.	44	1.7	170	8
Sabine River RM 40	DO	151	Arith.	6.4	1.6	10.1	0.7
	pH	151	Arith.	7.2	0.4	8.2	6.1
	Cl	151	Log.	41	1.6	160	10
Sabine River RM 26	DO	21	Arith.	6.3	2.4	9.5	2.8
	pH	20	Arith.	7.2	0.2	7.5	6.6
Sabine River RM 14	DO	98	Arith.	5.7	2.1	9.4	1.1
	pH	98	Arith.	7.1	0.4	8.0	6.2
	Cl	98	Log.	39	2.0	520	3
Sabine River RM 2	DO	409	Arith.	5.2	1.4	10.5	1.9

* pH in pH units

Source: Forest and Cotton, Inc., representing the Sabine River Authority[18/]

Table 10

Characteristic Analyses of Ground Water from the Primary Aquifers in the Sabine River Basin

Constituent	Carrizo-Wilcox Aquifer (19 wells) Concentration mg/l			Gulf Coast Aquifer (7 wells) Concentration mg/l		
	Mean	Max.	Min.	Mean	Max.	Min.
Silica	18	45	10	48	56	34
Iron	2	21	0	14	27	.07
Calcium	11	103	0.5	15	34	2.0
Magnesium	3	24	0	2.1	5.4	0.5
Na+K	308	843	42	63	170	9
HCO_3	504	894	49	128	225	31
SO_4	39	335	0	5	0	0
Cl^-	160	825	8.2	51	196	3.5
F	0.8	2.8	0	0.2	0.4	0
NO_3	0.8	3.0	0	0	0	0
TDS	878	2,581	180	237	531	68
Total Hardness (as $CaCO_3$)	40	356	1	46	88	7
Specific Conductance (Micromhos)	1,186	3,450	303	446	927	102
Sodium Adsorption Ratio (SAR)	40	101	2.5	5.6	22	0.5
pH	7.9	8.8	6.7	6.8	7.6	5.5

Source: Texas Water Commission 19/

Table 11

Present Municipal Wastes

Sub-basin	Counties and/or Parishes	Quantity (mgd)	Waste Concentrations (mg/l) 5-Day 20°C BOD	Suspended Solids	Total Solids	Chlorides	Nitrates	Phosphates
I	Hopkins	0.016	25	100	222	75	22	24
	Hunt	1.573	20	40	383	91	22	24
	Rains	0.038	70	240	222	75	22	24
	Van Zandt	0.321	39	82	222	75	22	24
II	Gregg	6.310	2	27	336	101	23	24
	Harrison	2.030	14	21	371	110	22	24
	Panola	0.400	60	100	492	110	23	24
	Rusk	0.140	28	14	422	96	22	24
	Smith	0.279	17	22	362	85	22	24
	Upshur	0.049	45	158	222	75	22	24
	Wood	0.745	50	38	395	87	23	24
III	Sabine, Tex.	0.074	43	31	222	75	22	24
	Shelby	0.729	10	20	330	88	22	24
	DeSoto, La.	0.130	275	295	330	90	22	24
	Sabine, La.	0.200	150	250	330	90	22	24
IV	Jasper	0.159	3	11	402	85	22	24
	Newton	0.140	4	14	316	87	22	24
	Orange	3.156	27	31	648	198	22	24
	Beauregard	No sewered municipalities in basin						
	Vernon	1.00	40	80	650	90	22	24
	Calcasieu	No sewered municipalities in basin						
	Cameron	No sewered municipalities in basin						

Source: Bryant-Currington, Inc., [7] Public Health Service, [11] and Louisiana State Board of Health [12]

	Load, tons/day [10] [11]
5-day 20° C. BOD	7.3
Suspended Solids	16.3
Total Solids	428.0
Chloride	517.0
COD	109.2
Sulfates	50.3

Most of the industries provide some form of treatment for their wastes or have treatment facilities in the planning stage. Some problems of organic pollution in Subbasin IV occur as a result of inadequate treatment of chemical and petroleum refinery wastes.

(3) Irrigation Return Flow.- According to the 1964 irrigation inventory [13] there were 9,005 acres irrigated in the basin. The actual return flow quantities are unknown, however, experience in the area indicates that 32 percent of the diversion requirement for rice, and 44 percent for other crops would eventually return to the stream. It was further assumed that the quantity of pollutants in the irrigation source water will be returned to the stream in order to prevent pollutant buildup in the soil. Estimated 1964 irrigation return flows by subbasin are shown in table 12.

(4) Agricultural.- Analyses for chlorinated hydrocarbon pesticides have been made on carbon adsorption method samples and two grab samples from the Sabine River near Ruliff, Texas taken between 1957 and 1965. None of the chlorinated hydrocarbons were detectable in the carbon adsorption system samples. In 1964, however, the grab sample was presumed positive for Dieldrin, and in 1965 the grab sample was presumed positive for Heptachlor and also Heptachlor Expoxide. [14] Although there is apparently no pesticide problem in the Sabine River at present, occasional synoptic surveys should be continued.

(5) Natural.- An area of natural salt pollution occurs on Grand Saline Creek in Van Zandt County. Grand Saline salt dome, which lies near the ground surface, is overlain by a salt falt. Small quantities of highly saline ground waters emerge in the flat and flow into Grand Saline Creek. Spot samples indicate concentrations of chloride and total dissolved solids as high as 39,200 mg/l, and 66,200 mg/l, respectively, in one of the small streams which drains the salt flat. A comparison of the chloride content of Grand Saline Creek above and below the salt flat indicates that the contribution of chlorides to the Sabine River from this source in February 1963 was on the order of 25 tons of chloride per day. [15]

(6) Oilfield.- There are in excess of 100 oilfields in the Sabine River basin. See plate 3. Oilfield related pollution by brines occurs in Dry Creek, (an arm of Lake Fork Creek), Rabbit Creek,

Table 12

1964 Irrigation Return Flows

Subbasin	Counties and/or Parishes	Return Flow* (acre-feet)	Waste Concentration (mg/l) 5-Day 20°C BOD	Total Dissolved Solids	Chlorides	Sulfates
I	Hopkins	27	1.0	176	10	22
	Hunt	48	1.0	176	10	22
	Rains	3	1.0	176	10	22
	Van Zandt	55	1.0	176	10	22
II	Gregg	3	1.0	140	42	24
	Harrison	18	1.0	140	42	24
	Panola	19	1.0	140	42	24
	Rusk	27	1.0	140	42	24
	Smith	147	1.0	140	42	24
	Upshur	0	-	-	-	-
	Wood	85	1.0	140	42	24
III	Sabine, Tex.	0	-	-	-	-
	Shelby	0	-	-	-	-
	DeSoto, La.	0	-	-	-	-
	Sabine, La.	0	-	-	-	-
IV	Jasper	53	1.0	200	55	30
	Newton	395	1.0	200	55	30
	Orange	4206	1.0	200	55	30
	Beauregard	0	-	-	-	-
	Vernon	0	-	-	-	-
	Calcasieu	1600	1.0	200	55	30
	Cameron	0	-	-	-	-

Source: *Soil Conservation Service 13/

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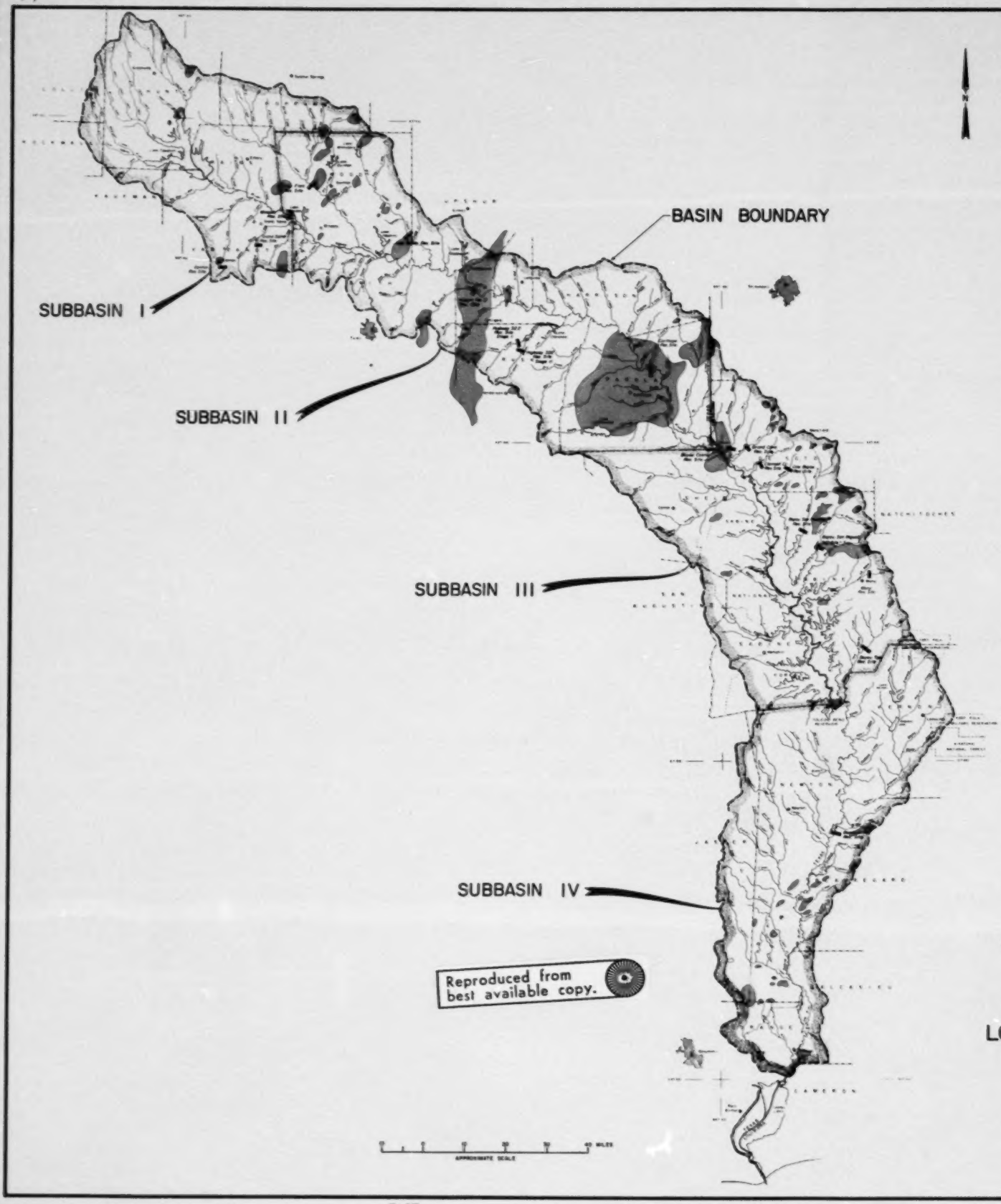

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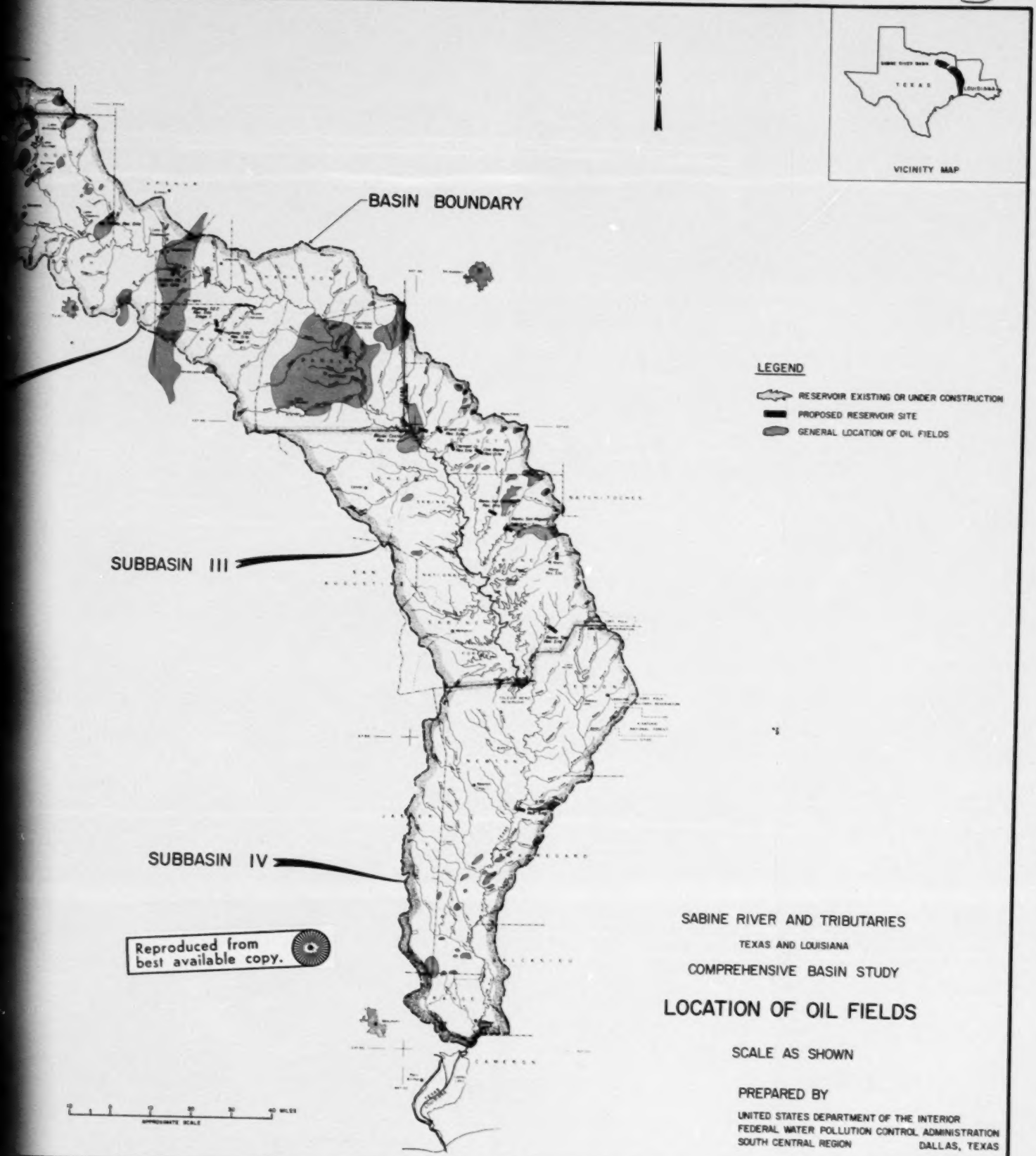

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SABINE RIVER AND TRIBUTARIES

TEXAS AND LOUISIANA

COMPREHENSIVE BASIN STUDY

LOCATION OF OIL FIELDS

SCALE AS SHOWN

PREPARED BY

UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTH CENTRAL REGION DALLAS, TEXAS

PLATE 3

and Socagee Creek. A continuing program of abatement of these pollution sources is carried on by the Texas Railroad Commission, and the Louisiana Stream Control Commission. At present, 85 to 90 percent of the brine produced from these operations is injected into subsurface formations. In addition, old or abandoned wells are being effectively plugged by the State agencies.

This practice poses little danger of polluting fresh ground water and surface water supplies provided the following conditions are met: suitable geologic conditions, properly constructed wells, no excessive pressures, proper casing of nearby oil wells, and proper plugging of abandoned wells. The widespread practice of water flooding in oilfields and the reinjection of oilfield brines should be watched carefully.

According to the 1961 salt water inventory of the Texas Water Commission, a total of 150,192,937 barrels of brine were produced in that year in the Sabine River basin. Of this total, 133,258,462 barrels were reinjected into subsurface formations, 10,642,462 barrels were retained in surface pits, and 5,100,680 barrels flowed into streams. The disposition of the remaining 1,191,620 barrels was either unknown or not reported. 16/

Similarly, in 1956, the Louisiana Stream Control Commission reported an annual brine production of 8,396,916 barrels in that State's portion of the Sabine River basin. Of this total, 5,353,392 barrels were disposed of by surface pit impoundment, and 3,043,524 barrels were reinjected into subsurface formations. 17/

Water quality problems caused by oilfield brine production are expected to diminish to insignificant proportions due to the continuing surveillance and enforcement procedures practiced by State regulatory agencies.

11. EVALUATION FACTORS.-

a. Stream Characteristics.- Some of the numerous factors which affect the amount of runoff or flow in the Sabine River basin are precipitation, temperature, seasonal rainfall distribution, storm intensity, infiltration rates, and types and density of vegetation.

Runoff rates in the Sabine River basin are relatively slow due to the topography and vegetal cover. The long narrow configuration of the watershed coupled with the lack of large tributaries prevent rapid accumulation of floodwaters. Low streambed gradients occur over much of the river's length. As the river meanders through its flood plain with numerous sloughs, overflow channels, and marshes, slopes of less than 0.8 foot per mile are not uncommon. 15/

The runoff in the Sabine River basin is about 25 percent of the precipitation and varies from 9 inches annually in the upper basin

to about 18.5 inches annually in the lower basin. The annual mean runoff at the lowermost gaging station near Ruliff, Texas (river mile 40.2) is 13.0 inches for the period 1925 to 1962. 15/

The range of annual mean discharge at the Ruliff gage is from 1,760 cfs to 17,210 cfs, while instantaneous flows varied from 270 cfs to 121,000 cfs. Similar variations in rainfall occur. The normal monthly rainfall at Longview, Texas varies from 2.56 inches in August to 5.72 inches in May. In 1962, however, the August total was only 0.30 inches, and the April total was 6.28 inches. 15/ This uneven distribution of precipitation does not sustain streamflow, necessitating storage projects to make surface water available in dependable quantities for municipal and industrial use.

b. Climatic Considerations.- Water temperatures are an important indicator in pollution control, not only because heat itself can be considered a pollutant, but also because temperature has a marked effect on dissolved oxygen and reaction time of most degradable pollutants.

From a water quality standpoint, evaporation exerts a concentrating influence on conservative pollutants. This effect is especially important in large surface reservoirs. In the Sabine River basin, the evaporation rates are relatively low, however. Mean annual reservoir evaporation rates range from 1.49 feet in the upper basin (Subbasins I and II) to 0.70 feet in the middle basin (Subbasin III) to 0.64 feet in the lower basin (Subbasin IV).

c. Water Quality Information.- The primary purpose of water quality investigations is the determination of the suitability of a water for a proposed use. In establishing this suitability, the chemical, physical, and sanitary characteristics of the water must be given consideration. Most existing and planned projects in the Sabine River basin are for municipal and industrial use. Generally, water suitable for these purposes will also satisfy the quality requirements for other legitimate water uses. Water quality information desirable for various water uses is shown in table 13.

d. Impoundments and Stream Regulation.- Some minor degradation of surface water quality could result from improperly operated impoundments and stream regulation facilities.

The concentrating effects of evaporation upon conservative pollutants should not be overlooked, even though no problems due to this phenomenon are expected in the Sabine River basin since evaporation rates are relatively low. Simiarly, the regulation of streamflow resulting from activities such as hydroelectric power generation and flood control could result in water quality degradation. If not reregulated, or checked, large flood or power pool

Table 13

Water Quality Information Desirable for Various Water Uses

Water Use	Item Applicable
Domestic water supply	Coliform organisms, total hardness, dissolved solids, pH, alkalinity, color, odor, turbidity, algae, floating solids, oil, sludge deposits, corrosive characteristics, iron, sulfate, fluoride.
Industrial water supply	Dissolved solids, total hardness, pH, alkalinity, temperature, color, turbidity, odor, floating solids, oil, sludge deposits, corrosive characteristics.
Fish and wildlife	Dissolved oxygen, pH, dissolved solids, algae, and other biological forms, turbidity, toxic constituents, salinity, temperature, and free carbon dioxide.
Recreation	Coliform organisms, floating solids, oil, sludge deposits.
Agricultural (Irrigation & livestock)	Dissolved solids, coliform organisms, floating solids, soil, sludge deposits, Salinity hazard measured, as Specific Conductance, in micromhos; and Sodium hazard measured, as the Sodium Absorption Ratio.
Transportation of wastes	Low streamflow, volume and strength of sewage, volume and character of industrial wastes. BOD, dissolved oxygen, temperature, coliform organisms, algae and other biological forms, floating solids, oil, sludge deposits.
Navigation	Dissolved oxygen, pH, corrosive characteristics.
Power	Dissolved oxygen, pH, corrosive characteristics.

releases cause scouring and increased turbidity. Downstream dissolved oxygen deficiencies also result from these operations where fixed withdrawal points are deep and take only the oxygen poor waters in the reservoir. Every effort should be made by construction agencies to assure proper design of outlet works to maintain the desired water quality.

12. FUTURE WATER QUALITY.-

a. Projected Wastes.- The quantity of municipal and industrial return flows is estimated as a percentage of water use. The municipal return flow percentage used varies from 45.8 percent to 82.5 percent, 20/ while industrial return flow percentages range between 23 percent and 90 percent. 21/

The quality of municipal return flows is based on assumed per capita contributions of 0.23 pounds per day of total dissolved solids, 0.013 pounds per day of chlorides, and 0.25 pounds per day of Biochemical Oxygen Demand (BOD) (ultimate first stage carbonaceous BOD). It is assumed that treatment will be provided to remove 85 percent of the BOD.

Industrial return flow quality is difficult to evaluate because of its variability with time, type of manufacturing process, type of product, production rate, cost of water, and many more factors. For purposes of this report, however, estimates were made of the concentrations of various pollutants resulting from industrial operations by industry groups (Standard Industrial Classification two digit categories 13, 14, and 20 through 39). Inherent in the estimates of conservative pollutants is the assumption that the concentrations of dissolved substances in the source water are additive with the industrial contributions. For the degradable pollutant used (BOD), it is assumed that industries which contribute this type of waste would provide treatment to the equivalent BOD concentration of a municipal waste that has been treated to remove 85 percent of the first-stage carbonaceous BOD. This concentration is 56 mg/l, based on a typical municipal sewage having an untreated concentration of 370 mg/l BOD.

No measurable return flow is expected to result from rural water use.

Experience in the area indicates that about 32 percent to 44 percent of the diversion requirements for irrigation water is returned to the watercourse. It was assumed that irrigation water would be applied in a manner that will prevent mineral buildup in the soil. Therefore, the dissolved solids load of the irrigation return flow would be the same as that of the source water and since less water is returned, the concentration would be increased.

It should be noted that much of the anticipated irrigation water use in the basin occurs near the mouth of the river. Return

flows from this irrigation would enter the river in or near the tidal reach of the streams where the inorganic quality of the water is less critical.

Brine wastes resulting from the secondary recovery of petroleum are not expected to cause pollution problems in the future. Continuing surveillance of these activities by the appropriate State agencies is expected to control this source of pollution through proper subsurface disposal practices.

The source of natural brine pollution on Grand Saline Creek in Van Zandt County, Texas is expected to continue to contribute a daily chloride load of approximately 25 tons. Due to the large volumes of dilution water available in the Sabine River, this pollution source does not appear to pose a serious water quality problem. In the event that development of the basin does not proceed as projected, remedial measures such as subsurface injection, should be investigated.

Future return flows by subbasin, together with expected pollutional loads from these sources for the years 1980, 2000, 2020, and 2075 are summarized in table 14.

b. Water Quality Goals.- Of the indicators available as a measure of water quality, dissolved oxygen, biochemical oxygen demand, total dissolved solids, chlorides, and sulfates are used in this study. These were chosen since adherence to appropriate limits on these indicators in the stream will adequately define the utility of a water to satisfy the projected requirements of the Sabine River basin. These uses are municipal, rural, recreational, industrial, fish and wildlife, irrigation, navigation, power, and waste transport.

The legitimacy of waste transport as a water use in a surface stream must be recognized if full use of the Sabine River basin to sustain projected economic development is to occur. It has long been known that all natural bodies of water have the ability to accomplish purification by oxidation of organic matter and by providing dilution for conservation substances dissolved in a water.

A comparison between the water quality requirements of the various water uses and the five quality indicators is shown in table 15.

Table 14

Future Return Flows and Pollution Loads

Subbasin	Pollution Source	Annual Return Flow Volume 1,000 Ac./Ft.	Treated Pollution Loads (Tons/Year) BOD	TDS	Cl	SO_4
			For the Year 1980			
I	M & I	3.7	281	1,635	462	55
	Irrigation	1.1	1	264	15	33
	Natural	4.9	7	15,855	8,028	1,673
II	M & I	54.7	3,580	27,100	7,650	1,745
	Irrigation	1.5	2	286	86	49
III	M & I	4.5	219	2,550	749	91
	Irrigation	0.1	-	41	16	7
IV	M & I	94.9	6,690	53,900	15,800	1,930
	Irrigation	18.0	24	4,898	1,347	735
Total Basin	M & I	157.8	10,770	85,185	24,661	3,821
	Irrigation	20.7	27	5,488	1,464	824
	Natural	4.9	7	15,855	8,028	1,673
			For the Year 2000			
I	M & I	6.0	459	2,673	754	90
	Irrigation	2.8	4	670	38	84
	Natural	4.9	7	15,855	8,028	1,673
II	M & I	69.1	4,033	30,578	8,630	1,970
	Irrigation	13.6	19	2,590	777	444
III	M & I	7.8	383	4,458	1,309	266
	Irrigation	0.3	-	122	49	22
IV	M & I	195.1	13,770	110,951	32,570	3,972
	Irrigation	19.1	26	5,197	1,429	780
Total Basin	M & I	278.0	18,645	148,660	43,263	6,298
	Irrigation	35.8	49	8,579	2,293	1,330
	Natural	4.9	7	15,855	8,028	1,673
			For the Year 2020			
I	M & I	10.8	836	4,786	1,351	162
	Irrigation	4.8	7	1,149	65	144
	Natural	4.9	7	15,855	8,028	1,673
II	M & I	89.3	5,220	39,576	11,168	2,549
	Irrigation	25.7	35	4,896	1,469	839
III	M & I	14.2	714	8,091	2,375	483
	Irrigation	0.5	1	203	81	37
IV	M & I	394.9	27,927	225,028	66,058	8,056
	Irrigation	19.1	25	5,197	1,429	780
Total Basin	M & I	509.2	34,697	277,481	80,952	11,250
	Irrigation	50.1	68	11,445	3,044	1,800
	Natural	4.9	7	15,855	8,028	1,673
			For the Year 2075			
I	M & I	24.5	1,899	10,862	3,065	367
	Irrigation	10.6	14	2,534	144	317
	Natural	4.9	7	15,855	8,028	1,673
II	M & I	182.7	10,684	81,000	22,859	5,218
	Irrigation	59.9	81	11,409	3,422	1,956
III	M & I	33.0	1,660	18,805	5,520	1,122
	Irrigation	1.1	2	449	180	82
IV	M & I	765.4	54,129	436,154	128,036	15,614
	Irrigation	19.1	26	5,197	1,429	780
Total Basin	M & I	1,005.6	68,372	546,821	159,480	22,321
	Irrigation	90.7	123	19,589	5,175	3,135
	Natural	4.9	7	15,855	8,028	1,673

Table 15

Water Quality Requirements for Various Water Uses

Type of Use	Concentration Spectrum (mg/l) Dissolved Oxygen	5-day 20°C BOD	TDS	Cl	SO_4
Municipal	-	-	≤ 500	≤ 250	≤ 250
Rural	≥ 5.0	0.75-2.5	≤ 500	≤ 250	≤ 250
Industrial	0-1.5	< 25.	75-1,500	20-900	20-200
Fish & Wildlife	≥ 3.0	< 5.0	≤ 2,000	≤ 1,000	-
Irrigation*	-	-	≤ 1,000	≤ 426	≤ 200
Navigation	-	-	-	-	-
Hydropower	-	-	-	-	-
Recreation	-	2.0-2.5	-	-	-

* Also SAR values between 0 and 10.

Source: U. S. Public Health Service,[22/] and George W. Burke, Jr.,[23/]

Careful examination of table 15 considering the types and varieties of projected uses and the relative costs of water treatment to remove unwanted constituents resulted in the following criteria for the five indicators used in this investigation. These criteria are used in determining the need for storage of water for quality control in proposed Federal reservoir projects.

Water Quality Criteria, Sabine River Basin

Indicator	Concentration
Dissolved Oxygen	≥ 4.0
BOD (5-day 20°C.)	≤ 5.0
Total Dissolved Solids	≤ 500
Chlorides	≤ 250
Sulfates	≤ 250

Protection levels, based on monthly means, for each type of water use were chosen. The level used for each water use is a function of the impact of a quality failure on the user. For instance, if the dissolved solids in a municipal water supply slightly exceed 500 mg/l for a short period of time, no measurable loss can be calculated. On the other hand, if the dissolved oxygen drops far enough below 4.0 mg/l for even several hours, damage to the fish population will have occurred. There is theoretically, then, some value of the probability of failure (taking into account the magnitude of failures) when resulting damages can be balanced against costs of maintaining a given quality condition. Unfortunately, in practice damages or losses resulting from water quality degradation are not easily quantified. The following protection levels are admittedly somewhat arbitrary, however, it is felt that they are reasonable in view of the present state of the art of water quality control.

Protection Levels for Various Water Uses

	Protection Level (Probability that the stated concentration will not be exceeded - percent)				
Type of Use	Dissolved Oxygen $\geq$ 4.0 mg/l	5-Day 20°C BOD $\leq$ 5.0 mg/l	TDS $\leq$ 500 mg/l	Cl $\leq$ 250 mg/l	SO_4 $\leq$ 250 mg/l
Municipal	80	80	95	95	98
Industrial	80	80	95	98	95
Rural	80	80	95	95	98
Fish & Wildlife	95	95	-	-	-
Irrigation	-	-	80	80	95
Navigation	-	-	-	-	-
Hydropower	-	-	-	-	-
Recreation	-	80	-	-	-

c. Water Quality Analysis.- In order to determine future water quality in the Sabine River basin, a mathematical model of the river system was constructed containing all reservoirs and points of withdrawal and inflow to the system. The Sabine Lake estuary was not considered in the computations. Determinations of quality were made at all points in the system using the historical as well as a generated trace of 100 years for flows.

The basic model computed the concentrations of BOD, TDS, Cl, and SO_4 at all points in the system. Because of computational space limitations on the computer used, dissolved oxygen was computed separately utilizing the same streamflows used in the basic model.

Computations were performed for three conditions, 1960, 1980, and 2020. Proposed reservoirs were added to the system as required to meet water needs in the latter two conditions. No quality computations were performed for the 2075 condition since this year is too far in the future to have any effect on storage space in reservoirs to be constructed within the next 20 to 25 years. Prior to actual construction of future reservoirs, the water quality computations should be reviewed as the findings of the present study will not be valid should economic development, or the timing thereof, in the basin be altered from that presently projected.

Results of the quality computations showed that the surface waters of the Sabine River basin will not be degraded below acceptable limits between the present and the year 2020. The probability of failure of all of the quality indicators was well within the limits chosen, and those failures that did occur were very small in magnitude as determined from a histogram analysis of the data.

13. WATER SUPPLY PLAN.- In developing a plan to satisfy the projected water requirements, recognition was given to plans of local interests, interstate compact agreements, and plans of the States of Louisiana and Texas.

The allocation of available waters to municipal and industrial, irrigation, and rural users by subbasin for the years 1960, 1980, 2000, 2020, and 2075 is shown in table 16. Estimates of future ground water use were made by increasing 1960 pumpage values 5 19/ in the basin by 10 percent. It was further assumed that all of the rural water use, which was not included in the Texas inventory, would be satisfied by this source. Based on in-basin water requirements, storage in Federal reservoirs is needed as follows: 29 mgd by 1980, 31 mgd by 2000, 117 mgd by 2020, and 841 mgd by 2075. Out-of-basin water transfer would increase these needs by 200,000 acre-feet per year (178 mgd) by 1980, as requested by the Texas Water Development Board.

14. PROJECT CONSTRUCTION SEQUENCE.- Prior to 1960, all reservoirs in the Sabine River basin were constructed by local interests. There are several more reservoirs presently under construction and more planned for future construction by various local and State agencies.

There are eight proposed Federal reservoirs in the basin. The sequence of construction for these projects, as well as for the local interest projects, was determined from local area requirement and supply studies, and incorporated in the water supply plan of this report. Of the five proposed Corps of Engineers projects, Mineola and Lake Fork Reservoirs are needed by the year 1980, Big Sandy Reservoir by 2000, Carthage Reservoir by 2020, and Bon Weir Reservoir after 2020. The three Soil Conservation Service projects, Canton, Grand Saline, and Many Reservoirs, are needed by 1980.

A proposed construction sequence for all reservoir projects is shown in table 17. This table includes existing and under construction projects.

15. WATER QUALITY CONTROL PLAN.- With conditions in the Sabine River basin as presently projected, and with the selected target concentrations of the indicator pollutants at the protection levels chosen, no storage of water for water quality control is anticipated. The water quality control plan does, however, presuppose that: (1) Brine wastes from oilfield operations will be controlled; (2) Secondary treatment (85 percent removal of BOD) will be provided for all municipal wastes; and (3) Treatment of industrial wastes equivalent to secondary municipal waste treatment will be practiced. The need for dilution water in the basin should be revaluated prior to actual construction of any Federal projects to determine whether the assumed conditions stated above and the development projected in this report are actually occurring.

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Table 16

Sabine River Basin Water Allocation

Area	User	Total Requirement (mgd)	Estimated Ground Water Use (mgd)	Surface Supply Requirement (mgd)	Surface Water Supply Source	Surface Water Supply Amount (mgd)	Estimated Return Flow (mgd)	Disposition of Return Flow (mgd) Disposal Stream	Disposition of Return Flow (mgd) Gaining Reservoir	Disposition of Return Flow (mgd) Amount Returned
For Year 1960										
Subbasin I	M&I	4.7	1.0	3.7	Greenville Reservoirs	2.2	1.9	Sabine	Tawakoni	1.6
	Rural	2.0	2.0	0	Small Lakes[a]	1.5	0		Sabine Lake	0.3
	Irri.	0.2	0	0.2	Run of Stream	0.2	0.1	Sabine	Tawakoni	0.1
Subbasin II	M&I	34.9	6.4	28.5	Lake Cherokee	16.1	10.0	Sabine	Sabine Lake	10.0
					Lake Gladewater	1.1				
					Lake Murvaul	2.3				
					Out of Basin[b] & Other	9.0				
	Rural	6.6	6.6	0			0			
	Irri.	0.3	0	0.3	Run of Stream	0.3	0.1	Sabine	Sabine Lake	0.1
Subbasin III	M&I	3.5	2.6	0.9	Small Lakes[a] & River Diversion	0.9	1.1	Sabine	Sabine Lake	1.1
	Rural	2.6	2.6	0			0			
	Irri.	0	0	0			0			
Subbasin IV	M&I	36.3	19.9	16.4	River Diversion	16.4	26.4	Sabine	Sabine Lake	26.4
	Rural	3.4	3.4	0			0			
	Irri.	18.3	1.8	16.5	River Diversion	16.5	9.1	Sabine	Sabine Lake	9.1
For Year 1980										
Subbasin I	M&I	10.1	1.1	9.0	Greenville Reservoirs	2.2	3.3	Sabine	Tawakoni	2.0
					Small Lakes[a]	1.9			Toledo Bend	1.3
					Tawakoni	4.9				
	Rural	2.5	2.5	0			0			
	Irri.	1.6	0	1.6	Run of Stream	1.6	1.0	Sabine	Tawakoni	1.0
Subbasin II	M&I	80.0	7.0	73.0	Lake Cherokee	16.1	48.8	Sabine	Toledo Bend	48.8
					Lake Gladewater	4.9				
					Lake Murvaul	9.5				
					Minnola	28.8				
					Kilgore Reservoir #2	4.0				
					Out of Basin[b]	12.7				
	Rural	8.5	8.5	0			0			
	Irri.	3.0	0	3.0	Run of Stream	3.0	1.3	Sabine	Toledo Bend	1.3
Subbasin III	M&I	8.1	2.9	5.2	Toledo Bend	5.2	4.0	Sabine	Toledo Bend	4.0
	Rural	3.6	3.6	0			0			
	Irri.	0.2	0.2	0			0.1	Sabine	Toledo Bend	0.1
Subbasin IV	M&I	137.9	21.9	116.0	Toledo Bend	116.0	86.7	Sabine	Sabine Lake	86.7
	Rural	4.3	4.3	0			0			
	Irri.	209.6	2.0	207.6	Toledo Bend	207.6	16.1	Sabine	Sabine Lake	16.1
For Year 2000										
Subbasin I	M&I	16.4	1.1	15.3	Greenville Reservoirs	2.2	5.4	Sabine	Tawakoni	0
					Small Lakes[a]	1.9				
					Tawakoni	11.2				
	Rural	2.7	2.7	0			0			
	Irri.	5.7	0	5.7	M&I Return Flow	5.4	2.5	Sabine	Tawakoni	2.5
					Run of Stream	0.3				
Subbasin II	M&I	103.2	7.0	96.2	Upper System[c]	47.1	61.7	Sabine	Toledo Bend	34.1
					Minnola	31.3				
					Out of Basin[b]	17.8				
	Rural	9.3	9.3	0			0			
	Irri.	27.6	0	27.6	M&I Return Flow	27.6	12.1	Sabine	Toledo Bend	12.1
Subbasin III	M&I	14.6	2.9	11.5	Toledo Bend	11.5	7.0	Sabine	Toledo Bend	7.0
	Rural	4.2	4.2	0			0			
	Irri.	0.6	0.2	0.4	Run of Stream	0.4	0.3	Sabine	Toledo Bend	0.3
Subbasin IV	M&I	278.1	21.9	256.2	Toledo Bend	256.2	176.2	Sabine	Sabine Lake	176.2
	Rural	4.9	4.9	0			0			
	Irri.	240.6	2.0	238.6	Toledo Bend	238.6	17.0	Sabine	Sabine Lake	17.0
For Year 2020										
Subbasin I	M&I	29.3	1.1	28.2	Greenville Reservoirs	2.2	9.7	Sabine	Tawakoni	0
					Small Lakes[a]	1.9				
					Tawakoni	24.1				
	Rural	3.0	3.0	0			0			
	Irri.	9.8	0	9.8	M&I Return Flow	9.7	4.3	Sabine	Tawakoni	4.3
					Run of Stream	0.1				
Subbasin II	M&I	140.5	7.0	133.5	Upper System[c]	70.6	79.7	Sabine	Toledo Bend	27.5
					Minnola	38.6				
					Out of Basin[b]	26.5				
	Rural	10.4	10.4	0			0			
	Irri.	52.2	0	52.2	M&I Return Flow	52.2	22.9	Sabine	Toledo Bend	22.9
Subbasin III	M&I	28.1	2.9	25.2	Toledo Bend	15.7	12.7	Sabine	Toledo Bend	12.7
	Rural	5.0	5.0	0	Run of Stream	9.5	0			
	Irri.	1.1	0.2	0.9	Run of Stream	0.9	0.5	Sabine	Toledo Bend	0.5
Subbasin IV	M&I	548.2	21.9	548.3	Toledo Bend	477.6	352.5	Sabine	Sabine Lake	352.5
	Rural	5.7	5.7	0	Run of Stream	68.7	0			
	Irri.	268.5	2.0	266.5	Toledo Bend	266.5	12.0	Sabine	Sabine Lake	17.0
For Year 2075										
					Greenville Reservoirs	2.2				
Subbasin I	M&I	66.4	1.1	65.3	Small Lakes[a]	1.9	21.9	Sabine	Tawakoni	0.6
					Tawakoni	26.2		Sabine	Minnola	0.1
					Lake Fork	35.0				
	Rural	2.8	2.8	0			0			
	Irri.	21.2	0	21.2	M&I Return Flow	21.2	9.5	Sabine	Tawakoni	4.7
									Minnola	4.7
Subbasin II	M&I	272.9	7.0	265.9	Upper System[c]	81.4	103.1	Sabine	Toledo Bend	41.6
					Minnola & Lake Fork	81.5				
					Carthage	29.8				
					Out of Basin[b]	47.0				
	Rural	10.1	10.1	0			0			
	Irri.	121.5	0	121.5	M&I Return Flow & Run of Stream	121.5	53.5	Sabine	Toledo Bend	53.5
Subbasin III	M&I	68.5	2.9	65.6	Toledo Bend	45.5	29.5	Sabine	Toledo Bend	29.5
	Rural	4.9	4.9	0	Carthage	20.1	0			
	Irri.	2.3	0.2	2.1	Run of Stream	2.1		Sabine	Toledo Bend	
Subbasin IV	M&I	1,110.7	21.9	1,088.8	Toledo Bend	440.6	683.3	Sabine	Sabine Lake	647.4
					Run Weir	297.3				
					M&I Return Flow and Run of Stream	350.9				
	Rural	5.6	5.6	0			0			
	Irri.	307.5	2.0	305.5	Toledo Bend	288.1	17.0	Out of Basin Sabine	Sabine Lake	17.0
					Run of Stream	17.4				

[a] Cities of Edgewood, Grand Saline, and Wills Point.
[b] City of Marshall.
[c] City of Hemphill.

[d] Upper Sys. ... include Lake Gladewater, Murvaul Lake, Kilgore Reservoir #2, Lake Cherokee, and Highway 322 Reservoir, Stage I.
[e] Same as for year of 2000 plus Stage II of Highway 322 Reservoir.

Table 17

Reservoir Construction Sequence by Subarea

Period	Subbasin	Reservoir	Dependable Yield (mgd)*		Agency
Existing Prior to 1960	1	Lake Tawakoni	208.1		Existing local interest
	1	Greenville Reservoirs	2.2		" " "
	1	Small Lakes	1.9		" " "
	2	Lake Cherokee	16.1		" " "
	2	Lake Gladewater	5.1		" " "
	2	Lake Murvaul	31.7		" " "
	3	Small Lake	0.3		" " "
1960-1980	1	Mineola Reservoir	83.4		Corps of Engineers
	1	Canton Reservoir	0.9		Soil Conservation Service
	1	Grand Saline Reservoir	1.9		Soil Conservation Service
	2	Kilgore No. 2 Reservoir	9.3		Local Interest
	2	Lake Fork Reservoir	161.6		Corps of Engineers
	3	Bayou Toro	32.0		Local Interest
	3	Many Reservoir	2.0		Soil Conservation Service
	3	Toledo Bend	1336.0	(1960-1980)	Local Interest
			1265.5	(1980-2000)	
			955.3	(2000-2020)	
			933.3	(2020-2075)	
	4	Lake Vernon	47.2		Local Interest Existing
1980-2000	2	Highway 322 Reservoir, Stage I	19.7		Local Interest
	2	Big Sandy Reservoir	65.9		Corps of Engineers
	3	Bayou Castor	28.0		Local Interest
	3	Bayou San Patricio	34.0		" "
	3	Cow Bayou	4.0		" "
2000-2020	2	Highway 322 Reservoir, Stage II	11.5		Local Interest
	2	Carthage Reservoir	305.1		Corps of Engineers
	3	Grand Cane	22.0		Local Interest
After 2020	3	Clement Creek	13.0		Local Interest
	3	Bayou San Miguel	31.0		" "
	4	Bon Wier Reservoir	297.3		Corps of Engineers

*Areal yields.

16. WATER BALANCE.- A water balance of resources versus needs in the Sabine River basin is shown in table 18. If the water supply plan as shown in this report is implemented, and projected development proceeds at the rate indicated, there will be surplus water in the basin to the year 2075.

17. WATER AVAILABILITY.- With existing and proposed reservoirs in operation, the water resources of the Sabine River basin for the years shown are given in table 19.

Table 19

Water Resources of the Sabine River Basin

Type of Resource	Dependable Yield (mgd)				
	1960	1980	2000	2020	2075
Surface Reservoirs	265.4	1,939.7	2,020.8	2,049.2	2,368.5
Imports	4.4	12.7	17.8	24.5	47.0
Ground Water	46.3	54.0	56.2	59.2	58.5
Return Flow	46.9	159.4	280.1	499.3	978.6
Uncontrolled Flow	2,912.0	1,531.2	1,531.2	1,531.2	1,137.4
Total Water Resource	3,275.0	3,697.0	3,906.1	4,163.4	4,590.0

18. LEGISLATIVE CONSIDERATION.-

a. Sabine River Compact.- The State of Texas and the State of Louisiana entered into a compact with respect to the waters of the Sabine River by Act of Congress of the United States, approved November 1, 1951 (Public Law No. 242; 82nd Congress, 1st sess.). The major purposes of this compact are to provide for an equitable apportionment between the States of Louisiana and Texas of the waters of the Sabine River and its tributaries, thereby removing the causes of controversy between the States over the conservation and utilization of said waters; to encourage the development, conservation, and utilization of the water resources of the Sabine River and its tributaries; and to establish a basis for cooperative planning and action by the States for the construction, operation and maintenance of projects for water conservation and utilization purposes on the reach of the Sabine River touching both States, and for apportionment of the benefits therefrom.

b. Interstate Stream Standards.- The Federal Water Pollution Control Act, as amended (43 U.S.C. 390b), was established to enhance the quality and value of our water resources and to establish a national policy for the prevention, control, and abatement of water pollution. As part of this act, the States are to adopt, before June 30, 1967, water quality criteria applicable to interstate waters

Table 18

Water Balance
(mgd)

Subbasin	Reservoir Yields a/	Imports	Ground Water	Return Flow	Uncontrolled Flow a/	Total Resource	Municipal and Industrial	Rural	Water Quality Control	Irrigation	Navigation	Exports b/	Fish & Wildlife	Total Requirements
For the Year 1960														
I	212.2	-	3.0	2.0	-	217.2	4.7	2.0	0	0.2	0	173.9	0	180.8
II	52.9	4.4	13.0	10.3	713.5	794.1	34.9	6.6	0	0.3	0	0	0	41.8
III	0.3	-	5.2	1.1	-	6.6	3.5	2.6	0	0	0	0	0	6.1
IV	0	-	25.1	33.5	2,198.5	2,257.1	34.3	3.4	0	16.5	0	1,081.7	380.3	1,716.2
TOTAL	265.4	4.4	46.3	46.9	2,912.0	3,275.0	77.4	14.6	0	17.0	0	1,255.6	380.3	1,944.9
							Surplus = 1,330.1 mgd							
For the Year 1980														
I	298.4	-	3.6	4.3	-	306.3	10.1	2.5	0	1.6	0	358.3	0	372.5
II	223.8	12.7	15.5	50.2	-	302.2	80.0	8.5	0	3.0	0	0	0	91.5
III	1,370.3	-	6.7	4.1	-	1,381.1	8.1	3.6	0	0.2	0	0	0	11.9
IV	47.2	-	28.2	100.8	1,531.2	1,707.4	137.9	4.3	0	50.2	0	1,180.8	380.3	1,953.5
TOTAL	1,939.7	12.7	54.0	159.4	1,531.2	3,697.0	236.1	18.9	0	55.0	0	1,539.1	380.3	2,429.4
							Surplus = 1,267.6 mgd							
For the Year 2000														
I	298.4	-	3.8	7.9	-	310.1	16.4	2.7	0	5.7	0	358.3	0	383.1
II	309.4	17.8	16.3	73.8	-	417.3	103.2	9.3	0	27.6	0	0	0	140.1
III	1,365.8	-	7.3	7.2	-	1,380.3	14.4	4.2	0	0.6	0	0	0	19.2
IV	47.2	-	28.8	191.2	1,531.2	1,798.4	278.1	4.9	0	53.3	16.5	1,196.9	380.3	2,130.0
TOTAL	2,020.8	17.8	56.2	280.1	1,531.2	3,906.1	412.1	21.1	0	87.2	16.5	1,555.2	380.3	2,672.4
							Surplus = 1,233.7 mgd							
For the Year 2020														
I	298.4	-	4.1	13.9	-	316.4	29.3	3.0	0	9.8	0	358.3	0	400.4
II	626.0	24.5	17.4	102.7	-	770.6	140.5	10.4	0	52.2	0	0	0	203.1
III	1,077.6	-	8.1	13.1	-	1,098.8	28.1	5.0	0	1.1	0	0	0	34.2
IV	47.2	-	29.6	369.6	1,531.2	1,977.6	568.2	5.7	0	53.3	18.6	1,046.9	380.3	2,273.0
TOTAL	2,049.2	24.5	59.2	499.3	1,531.2	4,163.4	766.1	24.1	0	116.4	18.6	1,405.2	380.3	2,910.7
							Surplus = 1,252.7 mgd							
For the Year 2075														
I	298.4	-	3.9	31.3	-	333.6	66.4	2.8	0	21.2	0	358.3	0	448.7
II	626.0	47.0	17.1	216.6	-	906.7	272.9	10.1	0	121.5	0	0	0	404.5
III	1,099.6	-	8.0	30.4	-	1,138.0	68.5	4.9	0	2.3	0	0	0	75.7
IV	344.5	-	29.5	706.3	1,137.4	2,211.7	1,110.7	5.6	0	53.3	19.1	842.1	380.3	2,411.1
TOTAL	2,368.5	47.0	58.5	978.6	1,137.4	4,590.0	1,518.5	23.4	0	198.3	19.1	1,200.4	380.3	3,340.0
							Surplus = 1,050.0 mgd							

a/ Data supplied by U.S. Army Corps of Engineers.

b/ Subbasin I diversions: 173.9 mgd in 1960, and 179.8 mgd by 1980 and thereafter from Lake Tawakoni for the cities of Dallas and Terrell, and 178.5 mgd (200,000 acre-feet per year) by 1980 and thereafter from Lake Fork and Mineola Reservoirs to the Trinity River basin. The quantity in Subbasin IV is Louisiana's share of basin waters, as provided in the Sabine River Compact, that are not anticipated to be needed by Louisiana in the basin. This amount includes projected out-of-basin irrigation diversions in Calcasieu Parish as follows: 159.3 mgd in 1980, 187.3 mgd in 2000, 215.2 mgd in 2020, and 254.2 mgd in 2075.

or portions thereof within their State. These "standards" could be different from the criteria used in this investigation. It is suggested that the water quality control plan in this report be reviewed at a later date to determine the significance of any variation from the adopted "standards", which could require a restudy of a particular phase(s) of the analysis.

WATER SUPPLY BENEFITS

The benefits of municipal and industrial water supply storage in Federal reservoirs result from improvements in quantity, dependability, quality, and physical convenience of water use. These reservoirs create aesthetic recreation areas for swimming, fishing, boating, camping, and water skiing accessible to those living in and near the study area. The sale of goods and services associated with these facilities usually becomes a significant segment of the economy of the area. Also, property values in the vicinity of the impoundments are improved. Finally, public health is benefited as municipal and industrial water users are provided with a dependable water supply having more uniform physical and chemical quality characteristics.

Senate document No. 97 (87th Congress, 2nd session) makes the following statement concerning evaluation of these benefits:

> "The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project."

After consideration of several other surface reservoir sites as well as additional ground water development, it is concluded that the most reasonable alternative to the four proposed Federal multipurpose projects in the Sabine River are single-purpose reservoirs at the same locations.

In evaluating the benefits, the project life was taken as 100 years, and a 3 1/8 percent interest rate was used. Project development must be scheduled prior to the time of actual need to allow for planning, constructing, and filling the reservoir, and to provide a margin of safety. The year 1975 was considered as "present" for planning purposes.

To evaluate the cost of a single-purpose reservoir at the proposed reservoir site which is needed at the "present" time, the capital cost was converted to an equivalent annual cost and added to the annual operation and maintenance cost.

For a project not needed until a future date, a 100-year reservoir life would extend the economic evaluation beyond the time limits of this study. To be consistent with the time period used for calculating benefits for other uses in these multi-purpose reservoirs, the capital cost for the period from the year of need to

2075 was determined using the annual cost stated above. The capitalized cost was then discounted to "present" values and amortized over 100 years to give an average annual cost. Benefits were not calculated for long range projects, i.e., not scheduled for construction within the next 25 to 30 years.

A summary of the annual project benefits is shown in table 20, for both in-basin and total (includes out-of-basin transfer) requirements.

Table 20

Summary of Project Water Supply Benefits

Reservoir	First Cost ($)[1]	Annual Cost Amortized 100 years @ 3 1/8 % ($)	Annual Operation and Maintenance Cost ($)	Total Annual Cost ($)	Date of Need	Total Annual Benefit Discounted to 1975 @ 3 1/8 %	Yield (mgd)
Total Requirement (Includes out-of-basin transfer)							
Mineola	35,739,000	1,171,000	250,000	1,421,000	1975	--	83.4
Lake Fork	45,144,000	1,479,000	255,000	1,734,000	1975	--	161.6
Big Sandy	16,986,000	556,000	220,000	776,000	1985[2]	400,000	65.9
In-Basin Requirements							
Lake Fork	45,144,000	1,479,000	255,000	1,734,000	1975	--	161.6

1/ Includes interest during construction; construction cost furnished by the Corps of Engineers.
2/ To meet the objectives of the State water plan, the Texas Water Development Board has requested Big Sandy Reservoir be constructed by about the year 1995. Project development was scheduled by 1985 to allow time for planning, construction, and filling the reservoir.

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